International Journal of Electronics Engineering, 1(2), 2009, pp. 189-192

Application of the OFDM Modulation to Power Line Communications

Archana Agarwal

EEE Department, YMCA Institute of Engineering, Faridabad, Haryana (INDIA)

Abstract: *Power line communication (PLC) is one of the most attractive communication methods for in home networks. The ubiquitous power line has been utilized as a physical layer for building communication mainly because of the availability of a preinstalled infrastructure. In power line communications, multicarrier modulation is an efficient way to transmit information at a very high data rate. OFDM has developed into a popular scheme for wideband digital communication, wireless as well as over copper wires (used in PLC). The primary advantage of OFDM over single carrier scheme is its ability to cope with severe channel conditions- for example, attenuation of high frequencies in a long copper wire. This paper analyzes a possible way of using OFDM technique to multimedia communication over power line.*

Keywords: *Multicarrier Modulation, Power Line Communication, Orthogonal Frequency Division Multiplexing, Gaussian Minimum Shift Keying.*

1. INTRODUCTION

The power line can be used for creating an in-house network or for bridging the last mile between the transformer station and the access point of the end-user without the necessity of additional cabling and additional interface (wall outlet). Each wall outlet can be used as an access point to this network. The electrical distribution power grid could turn out to be an ideal candidate to cope with existing standard communication links based on copper wiring, applications which will be implemented are: Internet Web browsing, Internet telephony (Voice over IP) and security applications. As we can see the new power line communications system will have multimedia capabilities.

There are some aspects that limit the data rate: regulatory and technical aspects. In Europe, residential power line communications is allowed in frequency band 3-148.5 kHz. This frequency band is standardized by committee European de Normalization Electro technique (CENELEC), regulation EN50065-1. Since communications signals on the low voltage network cause degradation in power quality, transmission power levels kept being low, Table 1. If this standardization continues broadband residential power line communication will be the next stage of standardization process. As the power line has been designed for distribution of energy and not for transmission of data there are most unfavorable: varying impedance, considerable noise, high attenuation, many reflected waves and other effects. Using adaptive equalization techniques could solve these problems, but there are practical difficulties in operating this equalization in real time at several Mb/s with compact low cost hardware. Recent analyzes, [1] have been proved that modulations that uses broadband with one or more carriers would be a good choice for data transmission over power lines. A promising candidate that eliminates a need for complex equalizers is the Orthogonal Frequency Division Multiplexing (OFDM), a multicarrier technique. The paper is organized as follows. In next section structure of electricity power distribution grid is presented. Then the main communications characteristics of power line channel and the basics of OFDM modulation technique and analysis are discussed. The last section contains concluding remarks.

*Corresponding Author: archana_aggrawal@yahoo.co.in

Table 1
CENELEC Frequency Range

Band	*Frequency range*	*Usage*
	3kHz-9kHz	Limited to energy providers, However, with their approval it may also be used by other parties inside consumer premises.
A band	9kHz-95kHz	Limited to energy providers and their concession holders.
B band	95kHz-125kHz	No access protocol is defined for this frequency band.
C band	125kHz-140kHz	In order to make simultaneous operation of several systems with in this frequency band possible, a carrier-sense multiple access protocol using a centre freq of 132.5kHz was defined.
D band	140kHz-148.5kHz	No access protocol is defined for this frequency band.

2. STRUCTURE OF THE ELECTRICITY POWER DISTRIBUTION GRID-

Electricity power grid has three different voltage levels: the high voltages level with 110-400kV, the medium voltages level with 10-35kV and the low voltages level with 0.4kV. The different voltages levels transmit the electrical energy over different distances. The links between the voltage levels are transformer. This structure suggests the same hierarchical arrangement for communication system planning too.

The high voltage serves long distances between power plants and residential areas. The medium voltage lines runs into the different parts of the towns. The low voltage power distribution grid are especially interesting for development in the towns and thus for achieving a great number of customers. The low voltage power distribution network is of interest in this paper.

On the low voltage side of transformer substation the network is usually operated in star type. In cities a transformer substation usually supplies ten to four hundred households via six to eight outgoing feeders. All users connected to one feeder must share the same resources. In this situation only suitable multiple access scheme based on point to multipoint structure with master node in substation can handle simultaneous access of several users. At the customer premises the meter box represents a logical and practical interface between outdoor area of the responsibility of the public utility and the customer indoor area.

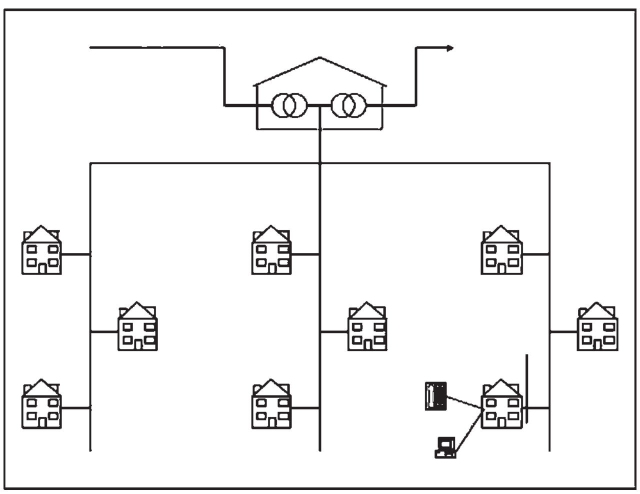

Figure 1: Local Area Network of a Distribution Transformer Substation.

3. COMMUNICATION CHANNEL CHARACTERISTICS OF THE POWER LINE-

The power lines are well suited for the distribution of high voltages at low frequencies, but transmission of data requires low voltages at higher frequencies and this is the reason why the conditions in the transmission channel are most unfavorable. Referring to measurements presented in [2], the network impedance is varying greatly frequency range of a few ohms and a few kilo ohms. At low frequencies impedance has inductive behavior and low impedance down a few Ω. The values of the maxima are in the range of a few kΩ. The positions of the maxima depend on location and network topology and may be between 4 MHz and 20 MHz. around the maximum the power line networks shows behavior like a parallel resonant circuit with inductive impedance below resonance frequency and capacitive impedance above. At higher frequencies the impedance becomes more resistive and has asymptotically behavior. The level of this asymptote is mainly affected by characteristic impedance of the power line, which is typically about 90Ω. Network impedance can approximate by a series arrangement of parallel resonant circuits. The highly varying network impedance is also the reason for very severe problem of impedance mismatch.

3.1. Channel Noise and Attenuation

The quality of signal is estimated from how good the communication is on channel. The quality is mostly a parameter of the noise level at the receiver and the attenuation of electrical at different frequencies. The higher the noise level the harder it is to detect the received signal. If the signal gets attenuated on its way to the receiver it could also make the decision harder because gets more hidden by the noise.

Measurement has been made at a voltage of 0.35Vrms on in-house lines, resulting in about 15dB attenuation, and on a 1km cable feeding a cluster of houses, resulting in 50db attenuation. In the range of frequency of 9-95 KHz the line losses ranged between 40-100dB/km depending on the location where the attenuation was measured [4].

In low voltage power lines, the source of noise can be internal (inside the power network) or external (outside the power network). Generally, channel noise varies strongly with frequency, load, time of day, and geographical location. The noise spectrum in the frequency range up to 145 KHz consists of five types of noise [3, 4, and 7]:

- Colored background noise, which is the summation of low power sources like universal motors. Its power spectral density is frequency dependent and decreases for increasing frequencies.
- Narrow band noise consisting of sinusoidal signals with modulated amplitudes (radio stations, the horizontal retrace frequency for television, etc.).
- Periodic impulse noise asynchronous to the main frequency, which is mostly caused by switched-mode power supplies.
- Periodic impulsive noise synchronous to the main frequency, which is mainly caused by switching actions of rectifiers diodes found in many electrical appliances [6].
- Asynchronous impulse noise, which is caused by switching transients in the power network.

Normally the root mean square (rms) amplitude of the first two types varies slowly over time, so that they can be summarized as background noise. On the other hand, the last three types can be regarded as impulsive noise since their amplitude change rapidly. Since the impulsive noise is actually produced by appliances in the power network, the power line noise can also be regarded as a combined sum of the background noise and impulsive noises from all near by appliances.

The noise power level ranges according to the distance between the noise source and receiver and in most cases was found to be below -40dB. It is worth mentioning that, since noise as well as wanted signals is subject to attenuation, noise sources close to the receiver will have the greatest effect on the received noise structure, particularly when the network attenuation is large.

4. POWER LINE COMMUNICATION TECHNIQUES-

An important factor referring to the robustness of technology PLC is the used modulation. A variety of techniques exists to connect a signal contents information to a signal of a carrier, who in this case it passes through in an electric grid, each one of them has advantages and disadvantages of which detaches the three following as most excellent ones:

- The technique of modulation of spread spectrum consists of distributing the power of the signal through out very ample bands of frequencies, in order to guarantee that the spectral density of power is sufficiently low. On the other hand, the width of necessary band of transmission of taxes in the order of Mbits raised.
- The technique of modulation Orthogonal Frequency Division Multiplex (OFDM) can be simply defined as a form of multicarrier modulation which divides the available spectrum into many carriers, each one being modulated by a low data stream. Carrier spacing is carefully selected so that each carrier is orthogonal, there is precise mathematical relationship, to the other carriers. OFDM uses spectrum more efficiently than FDMA (Frequency Division Multiplexing)
- The technique of modulation GMSK or Gaussian Minimum Shift Keying is a particular case of modulation OFDM to the times cited as OFDM of broadband. The carriers are modulated in phase, resulting in one “envelope” constant, in way that the amplifiers can be simpler. The signal is robust against interferences of short band such as radio controls of short waves. This modulation results in a specter of Gaussian form, from where it originates is denomination.

5. OFDM MODEL-

Orthogonal Frequency Division Multiplexing (OFDM) can be simply defined as a form of multicarrier modulation which divides the available spectrum into many carriers, each one being modulated with a conventional modulation scheme (such as Quadrature amplitude modulation). In OFDM, the subcarrier frequencies are chosen so that the sub carriers are orthogonal to each other, meaning that cross talk between the sub channels is eliminated and inter carrier guard bands are not required. This greatly simplifies the design of both the transmitter and the receiver; unlike conventional FDM, a separate filter for each sub channel is not required.

The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. This results in no interference between the carriers, allowing then to be spaced as close as theoretically possible.

Each carrier in an OFDM signal has a very narrow bandwidth; thus the resulting symbol rate is low. This results in the signal having a high tolerance to multipath delay spread, as the delay spread must be very long to cause significant intersymbol interference [5].

In practice, spectra of an OFDM signal is not strictly band limited (sinc (f) function); linear distortion such as multipath cause each sub channel to spread energy into adjacent channels and consequently cause intersymbol interference.

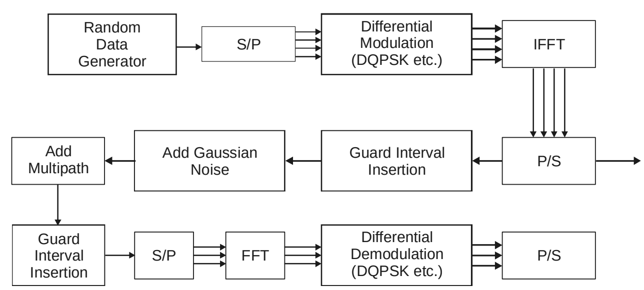

Figure 2: OFDM Model

A simple method is to increase symbol duration or the number of carriers so that distortion becomes insignificant. One way to prevent intersymbol interference is to add guard interval. Now symbol duration has two components: useful symbol duration and guard interval. When the guard interval is longer than channel impulse response or multipath delay the intersymbol interference can be eliminated. The ratio of the guard interval to useful signal is application dependent; it is usually four times smaller than useful signal.

As noted above, OFDM transmits a large number of narrowband carriers and in order to avoid a large number of modulators and filters at the transmitter and complementary filters [8] and demodulators at the receiver, it is desirable to be able to use modern digital signal processing techniques, such as Fast Fourier Transform (FFT). Also the use of phase shift keying produces a constant amplitude signal and was chosen for its simplicity and to reduce problems with amplitude fluctuations due to frequency selective channels [9].

6. CONCLUSION

Power line communication is a viable technology as demonstrated by several commercial products available today. Recent analyses have been proved that modulations which uses broad band with one or more carriers would be a good choice for data transmission over frequency selective channels as power lines. Because of its characteristics OFDM promises to be a suitable modulation technique for high capacity power line communications and will became important in the future.

REFERENCES

[1] E. Del Re, R. Fantacci, S. Morosi, and R. Seravalle, "Comparison of CDMA and OFDM Techniques for Downstream Power Line Communications on Low Voltage Grid", *IEEE Trans on Power Delivery*, **18**, (2003).

[2] Holger Philipps, "Performance Measurements of Power Line Channels at High Frequencies", Proc of ISPLCA, Tokyo, Japan, (1998).

[3] M. Gotz, M. Rapp, and K. Dostert, "Power Line Channel Characteristics and their Effect on Communication Design", *IEEE Communications Magazine*, (2004).

[4] O. Hooijen, "Channel Model for the Residential Power Circuit used as a Digital Communication Medium", *IEEE Trans. EMC.* **40**, (4), (1999).

[5] M. Zimmermann and K. Dostert, "A Multipath Model for the Power Line Channel," *IEEE Trans. Communication*, **50,** (2000).

[6] R.Vines *et al*, "Noise on Residential Power Distribution Circuits ," *IEEE Trans. Electromagnetic Compatibility*, **EMC-26**, (1998).

[7] O. Hooijen, "Channel Model for the Low Voltage Power Line Channel", Proc 1997 International Symposium on Power Line Communications and its Applications", Essen, Germany, (1997).

[8] B. Le Floch, M. Alard, and C. Berrou, "Coded Orthogonal Frequency Division Multiplexing", Proceedings of IEEE, **83**, (6), (1995).

[9] P. Siohan, C. Siclet, and N. Lacaille, "Analysis and Design of OFDM/OQAM Systems based on Filter Bank Theory," IEEE Trans. on Signal Processing, **50**, (5), (2002).